ACTIVE HYDROGEN MASER

VCH-1003M

Operations Manual

411141.032 OM

67, Osharskaya street, Nizhny Novgorod, 603105, Russia
"VREMYA-CH" JS Company,
Tel.- Fax: +7-831-421-02-94
E- mail: admin@vremya-ch.com, Web site: http://www.vremya-ch.com

Contents

1 INTRODUCTION

The VREMYA-CH Active Hydrogen Maser model VCH-1003M is intended to be used as a source of high stable low noise sine signals at standard frequencies and one pulse per second timing signals. It can operate both as standalone instrument and as a reference of time and frequency measurement systems. Remote control and parameters monitoring through RS-232 interface is provided.

The main maser's applications:

- Radioastronomy;
- Radionavigation;
- Time keeping;
- Scientific research.

The unique automatic cavity tuning techniques of cavity frequency switching method provides unsurpassed long term stability to be reached, typically less than 1×10^{-15} for a day. Properly set cavity tuning system parameters also doesn't degrade short term stability and eliminate frequency shift because of spin-exchange.

This method main advantage is that the maser requires no other stable frequency reference for its cavity to be tuned.

Figure 1 illustrates the maser VCH-1003M outward appearance.

Figure 1 Active Hydrogen Maser VCH-1003M

2 Specifications

2.1 Environmental conditions requirements:

- Normal temperature range is (20±5)ºC;
- Operating temperature range is 10ºC to 35ºC;
- barometric pressure range is from 84kPa up to 106 kPa (from 630 up to 795 mm Hg);
- Humidity range is 30% to 80% at 25ºC.

2.2 Power requirements:

- mains voltage from 85 to 264 VAC (47-63Hz);
- DC source or battery voltage is 22V to 30V.

The maser has one AC input and two separately fused DC inputs on its back. The power required is 150VA max on AC (with automatic crossover to DC) and 100 Watts max on 27V DC.

2.3 Output frequencies.

There are two 5 MHz, two 10 MHz, two 100 MHz sine signals with (1±0.2)V RMS outputs at 50Ohm load and two 1PPS timing signal outputs of positive polarity with the following parameters:

- amplitude ≥ 2.5V at 50 Ohm load;
- pulse length is 10µs to 20µs;
- rise time ≤ 15ns;

Sync of 1PPS signal is available to a similar signal applied to the sync input "⊕ 1 PPS". The sync error doesn't exceed ±50ns. Sync procedure is described in User Guide 411141.032 UG from the delivery set.

All sine signals have TNC type connectors and are located on the front of the maser. 1PPS signals both outputs and input have TNC type connectors and are also on the maser front panel. An additional output at 1400MHz with (13±2) dBm at 50 Ohm load is available as an option. This output of TNC-type is on the maser rear panel.

2.4 Stability, Allan variance is shown in Table 1:

Table 1 Active Hydrogen Maser VCH-1003M stability, time domain

Time domain	Allan variance	Comparator bandwidth, Hz	Notice
1s	1.5×10^{-13}	3	
10s	2.5×10^{-14}	3	
100s	6.0×10^{-15}	3	
1000s	2.0×10^{-15}	3 or 10	Cavity tuning mode
1h	1.5×10^{-15}	3 or 10	Cavity tuning mode
1d	7.0×10^{-16}	3 or 10	Cavity tuning mode

Notice: Environmental temperature changing range is ±1ºC at changing rate 1ºC/hour.

2.5 Temperature sensitivity is less than $\pm2\times10^{-15}$/ºC.

2.6 Magnetic field sensitivity is less than 1×10^{-14}/Gauss.

2.7 Harmonic distortion in 5 MHz output signal ≤-30dB;

2.8 Non-harmonic distortion ≤-100dB;

2.9 Phase noise (5MHz output) is shown in Table 2:

Table 2 Phase noise

Frequency offset, Hz	Phase noise, dB/Hz
1	≤-118
10	≤-135
100	≤-149
1000	≤-156
10000	≤-155

2.10 The output maser's frequency is adjustable in range to within 1×10^{-10} with resolution 1×10^{-16}. Remote frequency control is also available as described below.

2.11 The maser incorporates a frequency comparator for taking measurements of an external source of standard frequencies 5MHz, 10MHz or 100MHz with from 0.5V to 1V RMS at 50Ohm signals. The comparator input of TNC-type is labeled as "⊖ 100 MHz" on the front panel. The comparator measurements bandwidth is 10Hz. The additional stability is shown in Table 3:

Table 3 Stability of internal comparator, time domain

Time domain	Allan variance	Comparator bandwidth, Hz
1s	1.5×10^{-13}	10
10s	2.0×10^{-14}	10
100s	2.5×10^{-15}	10
1h	5×10^{-16}	10

Notice: Environmental temperature changing range is ±1ºC.

2.12 Warm-up time from a cold start is approximately 240 hours (10 days).

2.13 The maser is 550mm wide by 550mm deep by 1010mm high. The overall weight is 90 kg, in transportation crate 190 kg.

2.14 The maser lifetime is more than 15 years.

3 Delivery Set

Active Hydrogen Maser VCH-1003M delivery set is shown in Table 4

Table 4 Active Hydrogen Maser VCH-1003M delivery set

Item	Designation	Quantity	Notice
1. Active Hydrogen Maser VCH-1003M	411141.032	1	
2. Power cord	685670.100	1	AC power cord
3. Interface cable	685670.026-01	1	RS-232C
4. HF cable	685670.300	1	N/N 1.5m length
5. Interface adapter	UC232R-10	1	USB-RS232
6. Socket	2PMT14	2	DC power
7. Fuse	1 A	4	250V 1A
8. Fuse	3.15 A	2	250V 3.15A
9. Fuse	5 A	2	250V 5A
10. Adapter	33N-BNC-50-1/133NE	5	N/BNC
11. Certificate		1	
12. Operations manual	411141.031 OM	1	
13. User’s Guide	411141.031 UG	1	
14. Installation CD	00030-01	1	Software and documentation
15. Shipping crate	411915.002	1	

4 Brief description of the Maser and its operation

4.1 Active Hydrogen Maser VCH-1003M

Active Hydrogen Maser VCH-1003M structure is shown in Figure 2.

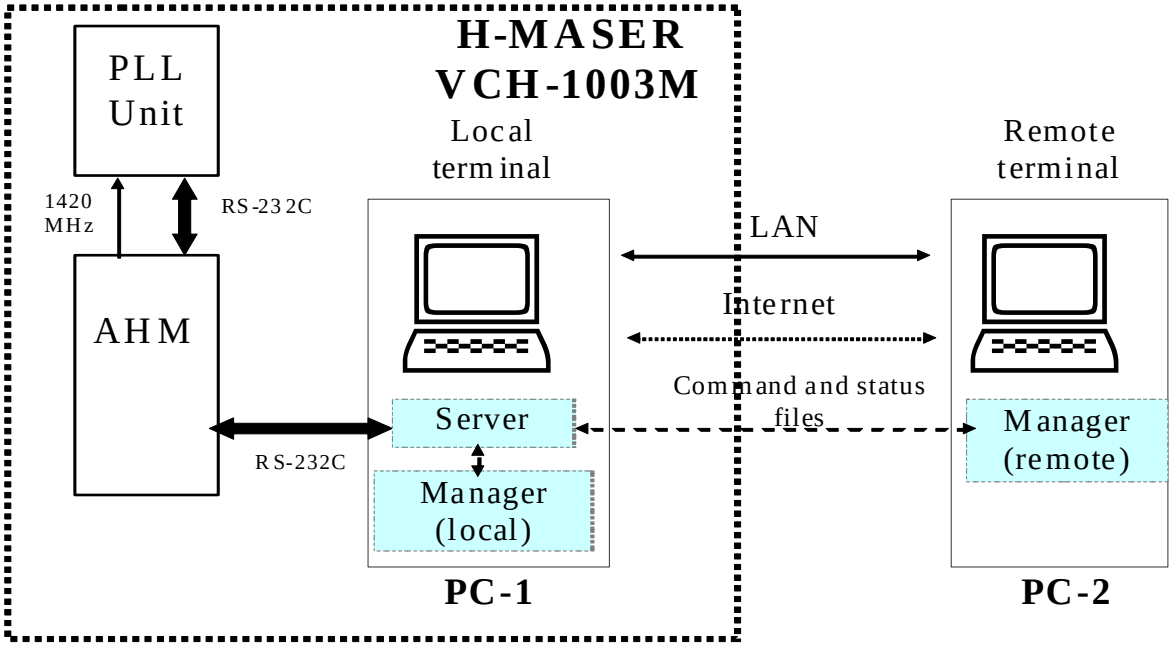


Figure 2 – Structure of the Active Hydrogen Maser VCH-1003M with the remote user's terminal

Designations in Figure 2 are the following:

AHM – Active Hydrogen Maser – Physics Package with surrounding units providing its operation such as a power unit, high voltage ion pumps, multi-level thermal control system, beam intensity stabilizer, source discharge oscillator and processor which enables all mentioned above units to be controlled and monitored via RS-232 connection.

Physics Package produces signal of hydrogen transition frequency 1420 MHz, applied to PLL Unit.

PLL Unit combines two functions. On the one hand it keeps a voltage controlled crystal oscillator phase-locked to the maser output. On the other hand it produces signals for cavity tuning. And so it assures the excellent maser performance.

Local terminal PC-1 contains Server and Manger software. Remote terminal PC-2 contains only Manager software.

PC-1 and PC-2 terminals both allow a User to take all information about maser operation he needs.

User may choose which terminal to control the maser from.

The software installation in detail is described in User Guide 411141.031 UG.

4.2 Physics Package

Figure 3 illustrates Physics Package Layout.

Small metal cylinder filled with intermetal combination of La Ni_5H_x is used as a molecular hydrogen source. When heated it releases hydrogen flow which goes to the Purifier. This is a thin wall nickel tube of spiral form. Beam stabilizer transmits the current of about 0.5A through the tube and so regulates the hydrogen flux to the discharge bulb where the source discharge oscillator dissociates them into atoms. Atoms emerge through the multichannel collimator and magnetic state selector, which directs a beam in right state into the Teflon coated storage bulb.

A microwave cavity causes the atoms to produce the microwave emission. Receiving loop transmits the hydrogen emission power outside to the low noise receiver. Hydrogen maser output power is about 100 -200 fW.

Two high voltage ion pumps and the getter provide vacuum inside the whole system.

Magnetic shields reduce the magnetic sensitivity of the maser and multi-level external and internal thermal system decreases temperature sensitivity significantly.

4.3 PLL Unit.

PLL Unit is intended to keep VCO 5MHz phase locked to the maser signal. The Multiplier forms from crystal oscillator signal standard outputs 100 MHz and output signal 1400 MHz.

The PLL Unit circuit is shown in Figure 4.

Low noise receiver transmits the maser signal 1420 MHz to the low frequency 405.7 kHz. This is the operating frequency of the Phase Detector. Another signal comes to the Phase Detector from the Synthesizer which is able to change the output frequency within 1×10^{-10} range with the resolution of 1×10^{-15}. Thus the Phase Detector controls the VCO frequency.

Frequency divider produces 1PPS timing signals. Sync input enables output signals to be synchronized to external 1PPS signal.

Processor provides the possibility of monitoring different PLL Unit parameters and controls the standard output frequencies via RS-232 port. For more detail information see User's Guide 411141.031 UG.

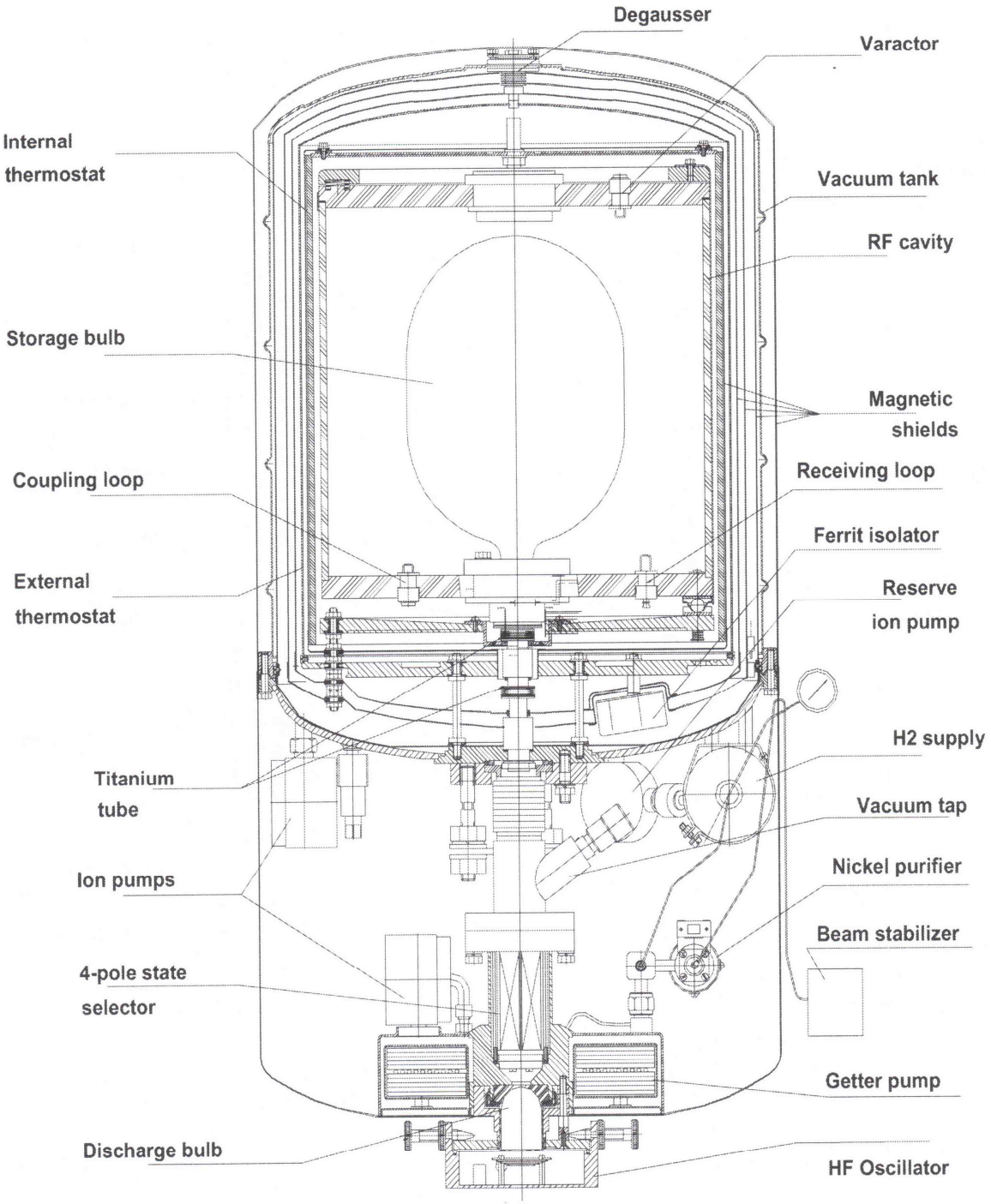


Figure 3 Physics Package Layout

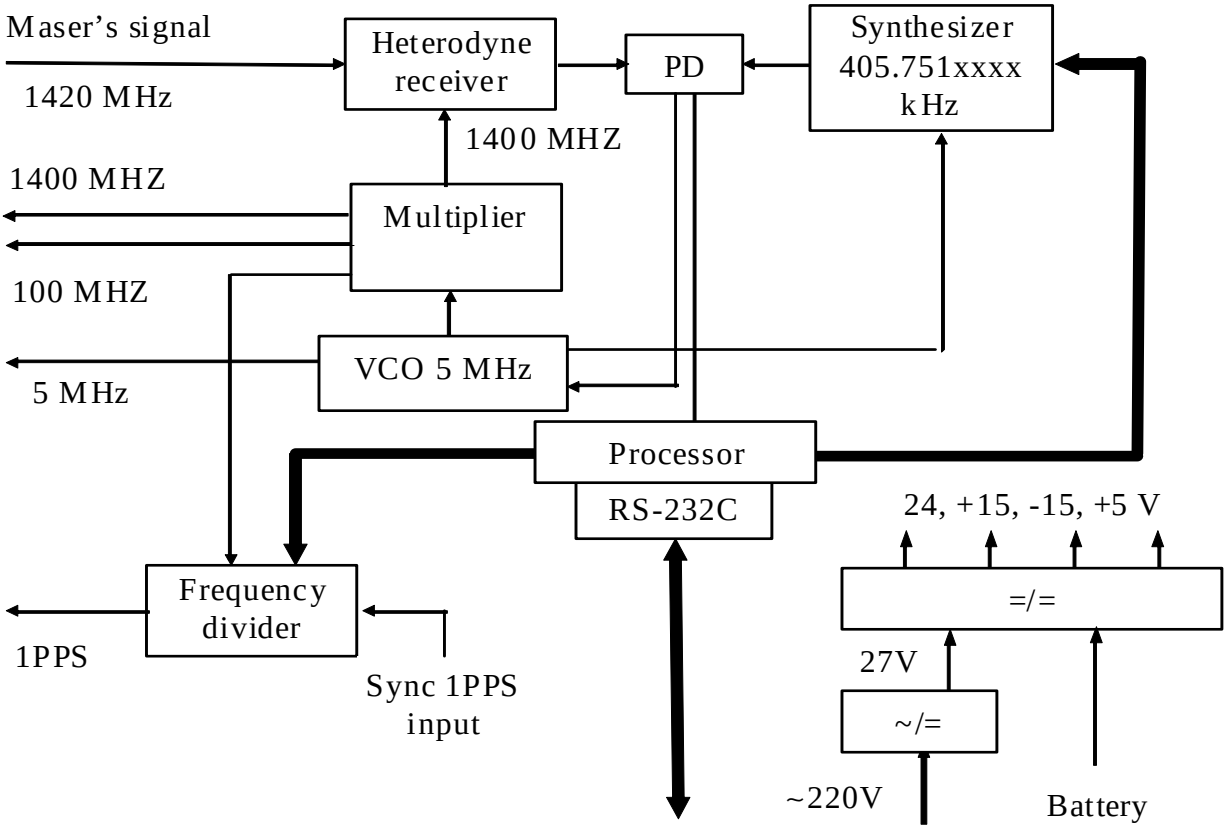


Figure 4 PLL Unit circuit

4.4 Cavity auto-tuning.

This auto-tuning system uses cavity frequency switching method in its operation.

Figure 5 illustrates its circuit.

Modulator changes data of modulating digital-to-analog converter DAC2 register with modulation frequency and its voltage applied to modulating varactor switches the cavity frequency.

Amplitude detector and low pass filter derives mistuning signal, which amplitude depends on cavity mistuning, from the maser signal and transmit it to synchronous detector. This detector changes DAC1 register and its voltage applied to tuning varactor shifts cavity frequency to the hydrogen emission line frequency.

Cavity tuning system parameters are adjusted at factory and are not to be changed by customer. Only tuning DAC readings are important during the operation.

For more details consult the User’s Guide 411141.031 UG

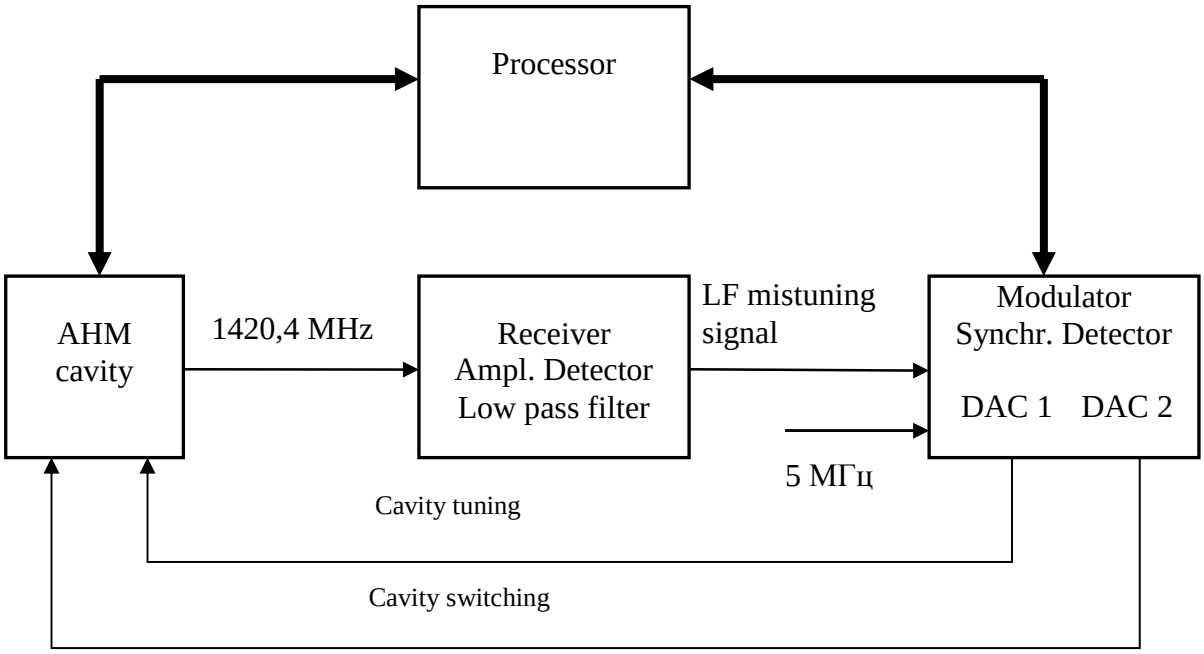


Figure 5 Cavity tuning system

5 Transportation and storage

5.1 The maser should be kept in vertical position during the transportation. It’s necessary to avoid heavy shocks and vibration, turning it over, ingress of moisture and dust. Environmental conditions are:

- Air temperature from -20ºC up to +50ºC;
- Humidity up to 90% at temperature +30ºC;

5.2 Storage conditions are:

- Air temperature from +5ºC up to +40ºC;
- Humidity up to 80% at temperature +25ºC;

The maser should be switched on monthly to start ion pumps for at least 30 minutes to avoid the vacuum loss inside the Physics Package. In 30 minute or 1 hour period high voltage current shouldn’t exceed 100μA.

6 Installation

6.1 Shipping crate unpacking

The maser unpacking has the following consequence (see Figure 6):

– Unscrew four nuts M16 from the top cover;

– Unscrew four bolts M12 from the top cover;

– Remove top cover carefully;

– Heel the crate slightly and unscrew four bolts M12 at the bottom;

– Unscrew eight cap screws from the front wall;

– Screw two ring-bolt at the opposite corners of the maser and using the pulley block lift the maser out of the crate gently and carefully;

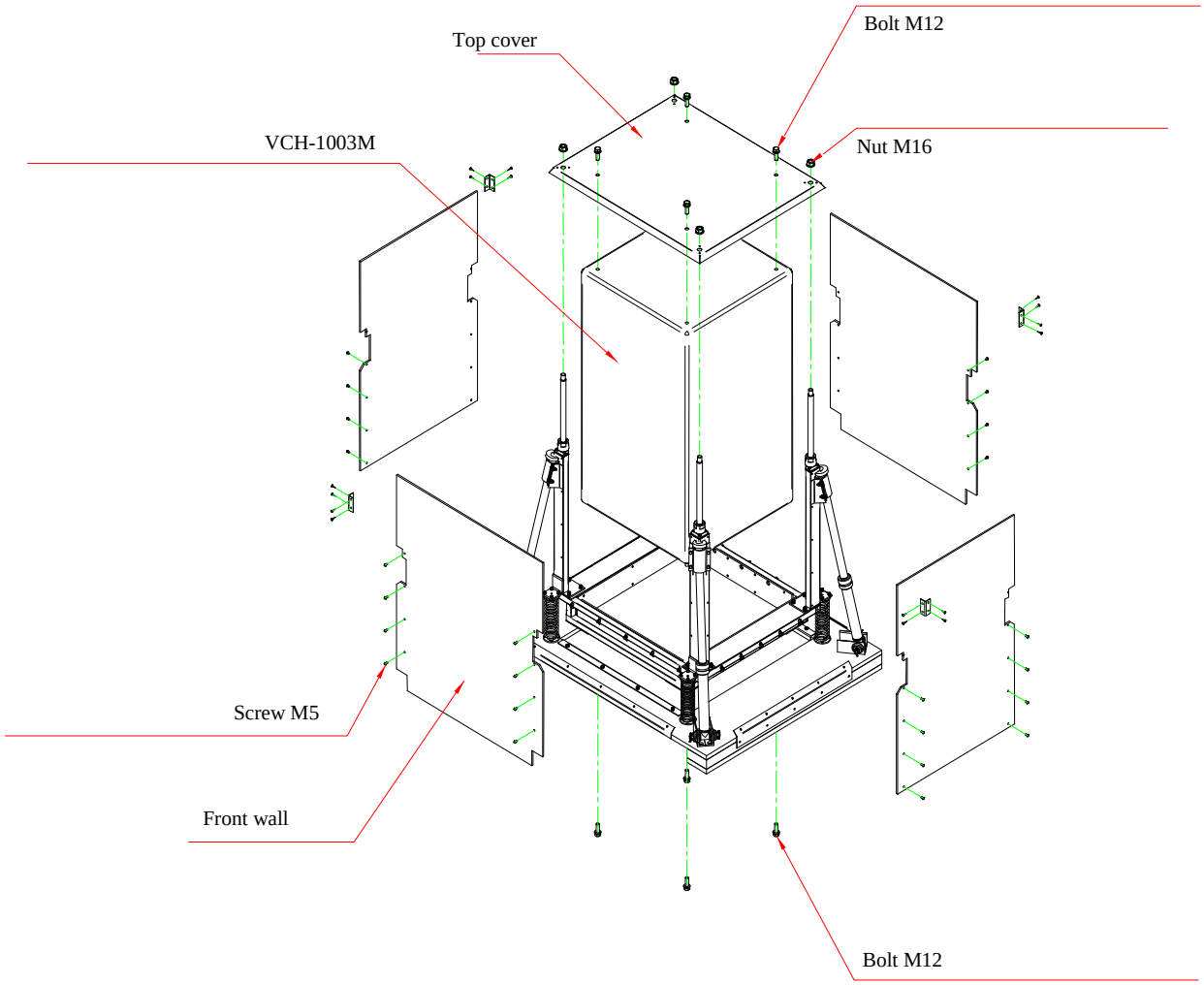


Figure 6 Shipping crate Layout

6.2 Starting up the maser

To achieve the best performance the maser should be located at the area with minimal temperature transition. The maser meets its specification only if environmental temperature changes within ±1ºC range at the rate slower than 1ºC/hour.

Please read the following information carefully before continuing.

Table 5 and Figure 7 describe indicators, connectors and switches on the maser's front panel.

Table 5 Indicators, connectors and switches on the maser's front panel

Items in figure 7	Designation	Description
1	POWER	LED indicator. It illuminates green when PLL Unit operates on AC power
2	BATTERY	LED indicator. It illuminates green when DC source is connected to the maser but PLL Unit still operates on AC power and blinks with a period about 1s when PLL Unit operates on DC power.
3	CAVITY TUNING	LED indicator. It illuminates green when the maser operates in cavity tune mode
4	PLL	LED indicator. It illuminates green when VCO is locked.
5	POWER	LED indicator. It illuminates green when the maser operates on AC power
6	POWER	Power switch.
7	BATTERY 1, 2	LED indicators. They illuminate green when DC source is connected to the maser DC input 1 or 2 correspondingly but the maser still operates on AC power and blink with a period about 1s when the maser operates on DC power.
8	→1 PPS	Sync input BNC-type
9	→100 MHz	Internal comparator input N-type
10	←10 MHz 1, 2	10 MHz sine signal outputs N-type
11	←1 PPS 1,2	1 PPS outputs BNC-type
12	←5 MHz 1,2	5 MHz sine signal outputs N-type
13	←100 MHz 1,2	100 MHz sine signal outputs N-type

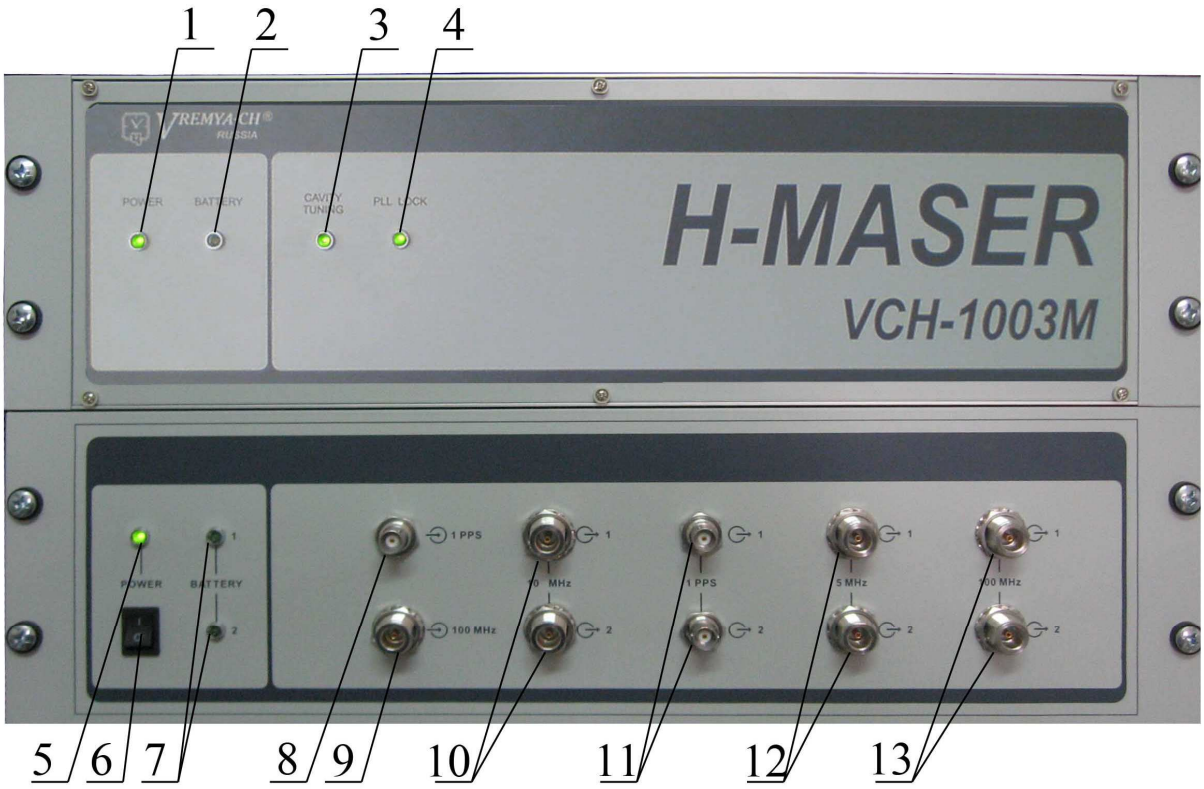


Figure 7 Indicators, connectors and switches on the maser's front panel

Table 6 and Figure 8 describe connectors and switches on the maser's rear panel.

Table 6 Connectors and switches on the maser's rear panel

Items in Figure 8	Designation	Description
1	RS-232C	Interface connector RS-232C
2	F1 5A, F2 5A	DC power connectors' fuses 250V 5A
3	F3 1A, F4 1A	AC power fuses of PLL Unit 250V 3.15A.
4	BATTERY 1, 2	DC power sources 1 and 2 connectors
5	F5 2A, F6 2A	DC power fuses of Physics package 250V 2A
6	~220 V 50 Hz 160 VA	AC power connector
7		1400 MHz output switch.
8	⊖►1400 MHz	1400 MHz output N-type. **WARNING! Don't leave this output switched on unloaded!** It may cause damage of the output amplifier.

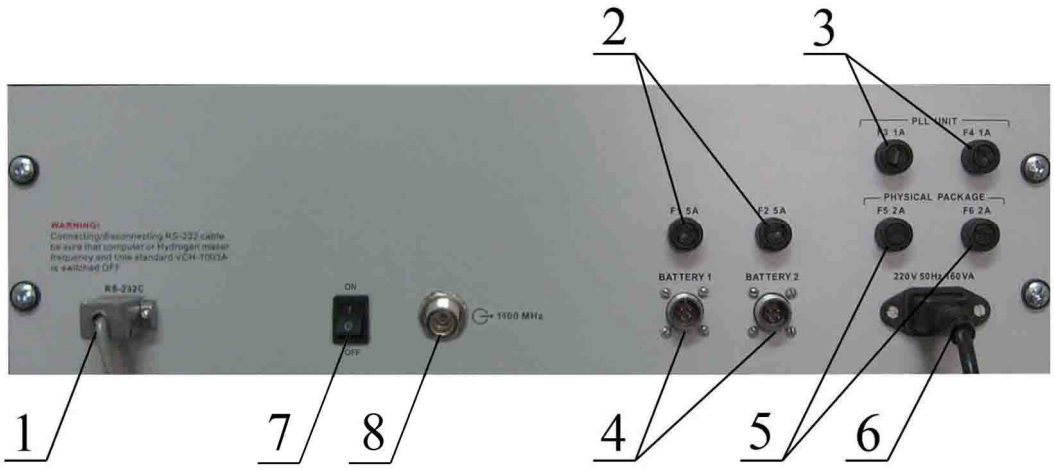


Figure 8 Connectors and switches on the maser's rear panel

Before switching the maser on connect RS-232 interface cable 685670.026-01 via interface adapter UC232R-10 to the computer USB port to avoid any interface damage. Then install the software on the computer according to the description in User's Guide 411141.031 UG and then start up the maser. Switch on the "POWER". Launch Server and Manager software and implement all procedures as it is describes in User's Guide 411141.031 UG.

To avoid any maser's operation disturbances due to AC power failures the continuous connection of DC power 24V sources is recommended.

7 Marking and identification

Trade mark of the manufacturer (1) and model of the maser (2)are located on the front panel (see Figure 9).

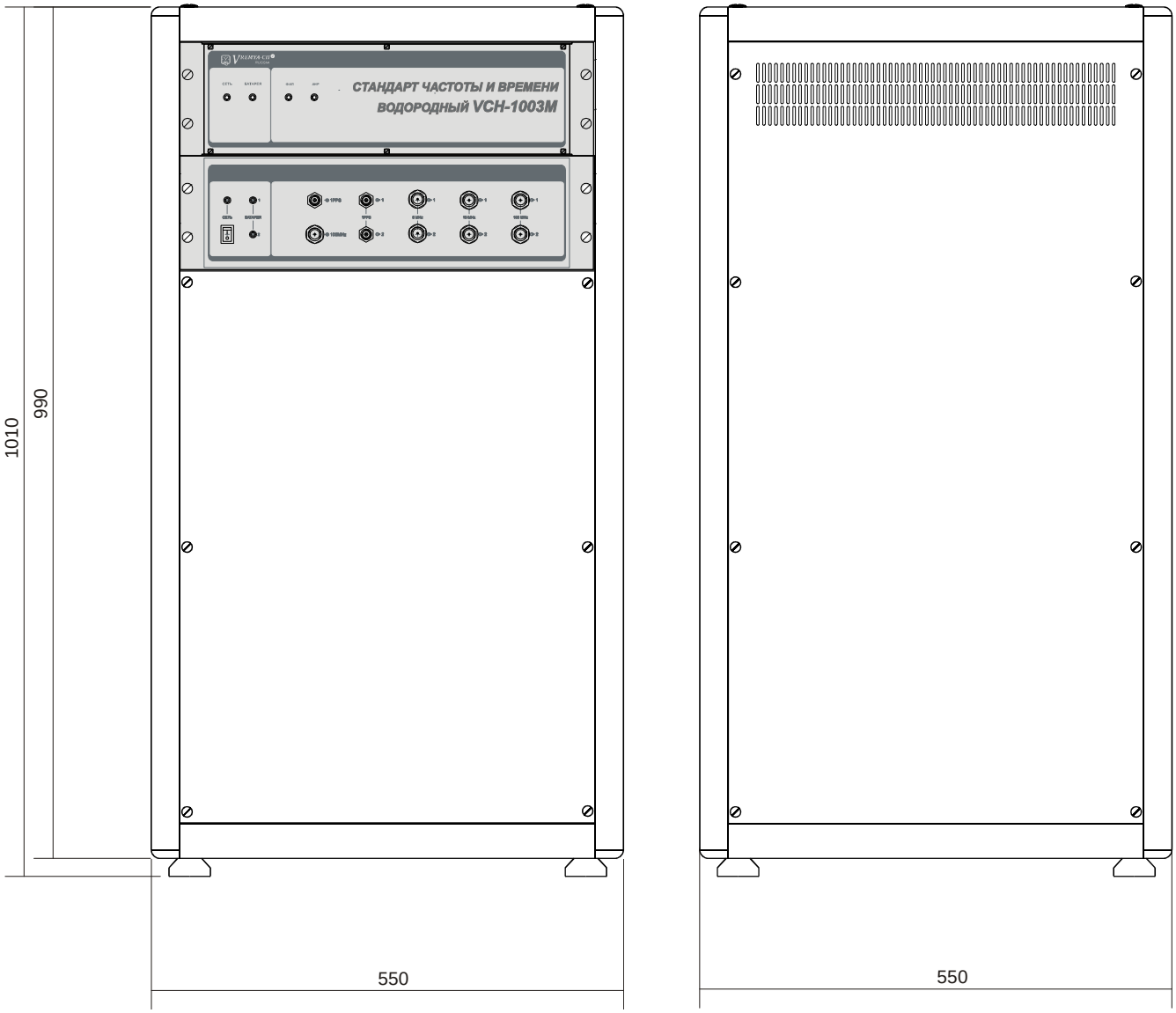
Serial number and production date are labeled on the back panel (1) (see figure 10).

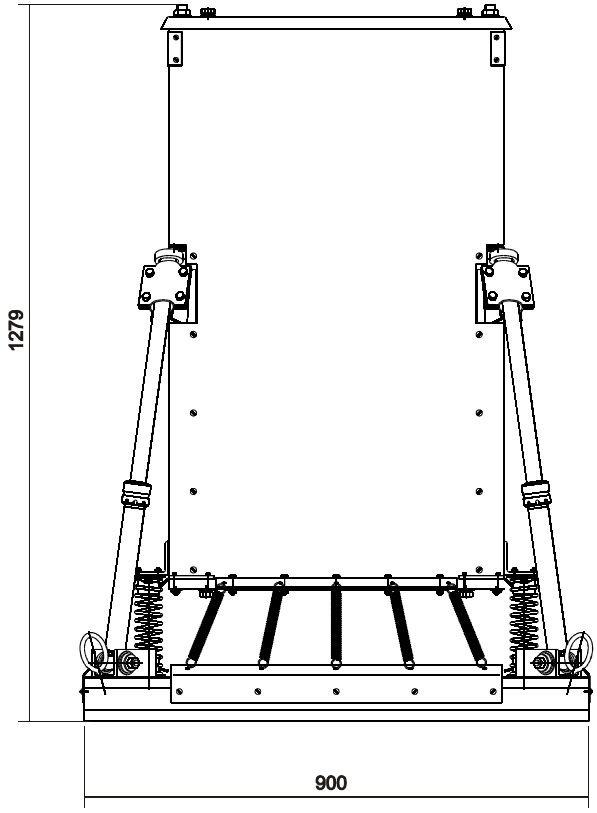
Figure 9 Trademark of the manufacturer (1) and model of the maser (2)

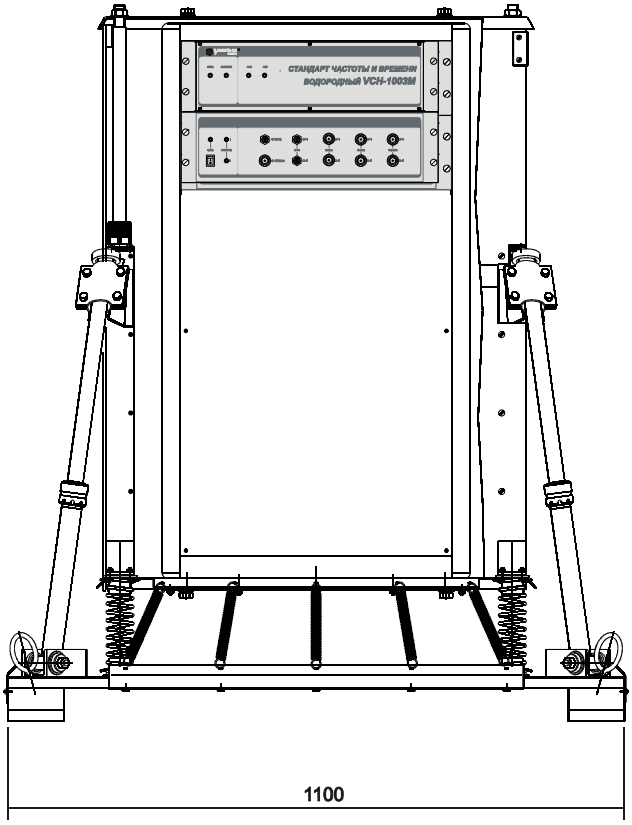
Figure 10 Serial number and production date label

Appendix A

Dimensions of the maser and shipping crate




1279
900


СТАНДАРТ ЧАСТОТЫ И ВРЕМЕНИ
ВОДОРОДНЫЙ VCH-1003M
1100